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**COHERENT PHASE SYNCHRONOUS CODE DIVISION MULTIPLE ACCESS
COMMUNICATIONS FROM MULTIPLE TRANSPONDER PLATFORMS**

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BACKGROUND OF THE INVENTION

The present invention relates generally to code division multiple access (CDMA) communications systems. More specifically, but without limitation thereto, the
10 present invention relates to a method for reducing the number of CDMA codes required for a group of subscribers serviced by multiple transponder platforms for synchronous CDMA communications.

Traditionally, when multiple satellites become
15 available over a given geographic location, two or more nearby users may not use the same frequency spectrum or code space due to interference. Also, as the number of subscribers within a service area increases, the frequency bandwidth, the number of CDMA codes, or both must be
20 increased to avoid interference from messages intended for other subscribers. The number of subscribers is therefore limited by the frequency bandwidth and the number of CDMA codes.

Methods for reducing the number of CDMA codes
25 for a service area effectively increase the bandwidth of the frequency spectrum by making a greater portion of the bandwidth available for subscriber communication rather than for separating messages intended for different subscribers.

30 Although multiple transponder platforms such as satellites increase the system availability, their full potential has been unrealized because of the limit on the

number of users imposed by the assigned frequency bandwidth and the number of available codes. In conventional asynchronous CDMA single satellite communication systems, unique CDMA codes are assigned to
5 each user to ensure that information directed to one subscriber does not interfere with information directed to another subscriber. Similarly, in multiple satellite communication systems, when two or more satellites are serving in the same geographical location, unique CDMA
10 codes within the same frequency bandwidth may be used to distinguish each subscriber. A problem with using the same CDMA code for multiple subscribers is that mutual interference prevents the proper decoding of information because the omnidirectional receiving antennas of the
15 subscribers' terminals lack the capability to discriminate spatially among the satellites.

SUMMARY OF THE INVENTION

The present invention advantageously addresses
20 the needs above as well as other needs by providing a method and apparatus for coherent phase synchronous CDMA communications between a gateway and multiple subscribers via multiple transponder platforms.

In one embodiment, the invention may be
25 characterized as a method for coherent phase synchronous CDMA communications between a gateway and multiple subscribers via multiple transponder platforms that includes the step of synchronizing a local reference clock for each subscriber in a service area to a single master
30 reference clock for multiple transponder platforms wherein the distance separating the transponder platforms is

constrained to a range wherein the local reference clocks for all subscribers have substantially the same phase with respect to the master reference clock.

In another embodiment, the invention may be
5 characterized as an apparatus for coherent phase
synchronous CDMA communications between a gateway and
multiple subscribers via multiple transponder platforms
that includes a transmitter for transmitting forward link
CDMA signals and a delayed synchronous CDMA message signal
10 from a gateway to an intended subscriber via each
transponder platform; a receiver for receiving return link
CDMA signals at the gateway from the intended subscriber
via each transponder platform; a propagation parameter
calculator for calculating message signal propagation
15 parameters from the return link CDMA signals; and a
reference clock synchronizer for synchronizing a local
reference clock of each subscriber to a master reference
clock of the gateway from the calculated propagation
parameters wherein the local reference clocks of all
20 subscribers have substantially the same phase.

The features and advantages summarized above in
addition to other aspects of the present invention will
become more apparent from the description, presented in
conjunction with the following drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features and
advantages of the present invention will be more apparent
from the following more specific description thereof,
30 presented in conjunction with the following drawings
wherein:

FIG. 1 is a diagram illustrating an exemplary multiple satellite communications system according to one embodiment of the present invention;

FIG. 2 is a block diagram of the gateway in FIG. 1 for coherent phase synchronous CDMA communications via multiple transponder platforms according to an embodiment of the present invention;.

FIG. 3 is a diagram comparing matched filter outputs for multiple CDMA code sequences arriving at a subscriber in phase and out of phase for the example in FIG. 1;

FIG. 4 is a diagram of the relationship between transponder platform separation and the angle of the subscriber from the transponder platform nadir for the example of FIG. 1; and

FIG. 5 is an exemplary flow chart for performing coherent CDMA signal reception according to another embodiment of the present invention.

Corresponding reference characters indicate corresponding elements throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE DRAWINGS

The following description is presented to disclose the currently known best mode for making and using the present invention. The scope of the invention is defined by the claims.

FIG. 1 is a diagram illustrating an exemplary multiple satellite communications system 10. In this example, single transponder satellites represent transponder platforms and cellular telephones represent

subscribers. Alternatively, the transponder platforms may also be carrier signal frequency reflecting surfaces, and the subscribers may also be fixed or mobile terminals. Other suitable devices with sufficient field of view to
5 cover the directions from which subscriber signals arrive and combinations thereof for relaying a signal from a gateway to a subscriber may also be used, whether fixed or mobile, on the ground, in the air, or in space. Similarly, subscribers may be any suitable devices and
10 combinations thereof employed for CDMA communications, whether fixed or mobile, on the ground, airborne, or in space.

A first forward link CDMA signal 120 is transmitted by a hub or gateway 104 to a first satellite
15 106 and relayed from the first satellite 106 to an intended subscriber 102. A second forward link CDMA signal 122 is sent by the gateway 104 to a second satellite 108 and relayed from the second satellite 108 to the intended subscriber 102. The sequence of forward link
20 CDMA signals may be sent at different times or otherwise arranged by well known techniques to avoid mutual interference. The subscriber 102 logs the time each forward link CDMA signal is received according to a local reference clock and inserts the time data in a return link
25 CDMA signal corresponding to each forward link CDMA signal received.

FIG. 2 is a block diagram of an exemplary gateway 104 in FIG. 1 for coherent phase synchronous CDMA communications via multiple transponder platforms. To
30 simplify referencing in the figures, indicia are used interchangeably for signals and their connections. The

reference 204 thus represents both the return link CDMA signals 204 from receiver 202 input by gateway 104 and the connection between receiver 202 and propagation parameter calculator 206. The propagation parameter calculator 206
5 calculates message signal propagation parameters 208 according to well known techniques from the return link CDMA signals 204 such as time delay, carrier frequency shift, and phase for each subscriber via each satellite. A delay calculator 210 inputs the calculated signal
10 propagation parameters 208 and calculates respective delays 212 for each subscriber via each transponder platform.

A reference clock synchronizer 214 provides a reference clock correction 216 from the calculated signal
15 propagation parameters 208 according to well known techniques for synchronizing the local reference clock of each subscriber to a master reference clock 218. To synchronize the message signals for all subscribers to the same reference clock for synchronous CDMA codes, the
20 distance separating the satellites 106 and 108 is constrained by the method of the present embodiment as explained below so that the local reference clocks of all subscribers have substantially the same clock phase. This feature of synchronizing each local reference clock to the
25 same master reference clock for all transponder platforms results in interfering messages having the same clock phase but not the same carrier phase as the message signal at the intended subscriber 102. Because all the CDMA signals have the same clock phase, they are synchronous,
30 and the signal-to-noise ratio is substantially enhanced at the subscriber 102 by better rejection of interfering

signals than is currently possible with asynchronous CDMA signals.

A transmitter 220 delays the message signal to the intended subscriber 102 by the respective delays 212 and transmits synchronous CDMA signals 250 from the gateway 104 to the intended subscriber 102 via each of satellites 106 and 108 so that message signals directed to the intended subscriber 102 arrive from the satellites 106 and 108 in coherent signal phase.

FIG. 3 is a diagram comparing matched filter outputs 30 for multiple CDMA code sequences arriving at subscriber 102 in phase in plot 302 and out of phase in plot 304 for the example in FIG. 1. The in-phase signals add constructively at the intended subscriber 102's location, increasing the signal strength over that of a single transponder platform according to

$$S = n_c^2 n_t^2 \quad (1)$$

where S is the signal power, n_c is the CDMA code length, and n_t is the number of transponder platforms. On the other hand, the same CDMA code sequences arrive with different phases at unintended subscriber 112 and appear as interference noise according to

$$N_I = n_c n_t \quad (2)$$

where N_I is the interference noise power. The signal-to-noise ratio for a typical subscriber is given by

$$\frac{S}{N_I} = \frac{n_c n_t}{n_u - 1} \quad (3)$$

where n_u is the total number of users, i.e., subscribers.

FIG. 4 is a diagram of the relationship between transponder platform separation and the angle of the subscriber from the transponder platform nadir for the example of FIG. 1. To synchronize the message signals for all subscribers to the same reference clock for synchronous CDMA codes, satellites 106 and 108 are preferably within a distance from each other given by

$$d \leq \frac{\Delta}{\sin \theta} \quad (3)$$

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where d is the separation 404 between transponder platforms 106 and 108, θ is the angle of a subscriber 402 at X relative to the transponder platform nadir 406 at O , and the tolerance Δ is a function of chip rate given

15 approximately by

$$\Delta \approx 0.1 \frac{c}{\text{chip rate}} \quad (4)$$

where c is the speed of light. For a typical chip rate of 4 Mhz, $\Delta = 0.1 \times 3 \times 10^8 \text{ msec}^{-1} / 4 \times 10^6 \text{ sec}^{-1} = 7.5 \text{ m}$.

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FIG. 5 is an exemplary flow chart 500 for performing coherent phase synchronous CDMA communications from multiple transponder platforms according to another embodiment of the present invention. At step 502 forward link CDMA signals are transmitted from the gateway 104 to the intended subscriber 102 via each transponder platform. At step 504 the return link CDMA signals are received from the intended subscriber 102. At step 506 the message signal propagation parameters are calculated from the return link CDMA signals. At step 508 a local reference clock of each subscriber is synchronized to a master

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reference clock from the calculated propagation parameters so that all messages arrive at all subscribers having the same clock phase. At step 510 the respective delays are calculated for the intended subscriber 102 via each of the 5 transponder platforms from the calculated signal propagation parameters. At step 512 a delayed synchronous CDMA message signal is transmitted from the gateway 104 to the intended subscriber 102 via each of the transponder platforms according to the respective delays so that the 10 delayed message signals arrive having the same signal phase at the intended subscriber 102 and having different signal phases at unintended subscribers 112.

Other modifications, variations, and arrangements of the present invention may be made in 15 accordance with the above teachings other than as specifically described to practice the invention within the spirit and scope defined by the following claims.